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APPROACHES TO THE PROCEDURE OF FUNDING BY COUNTRIES OF WATER MANAGEMENT SYSTEM FACILITIES ON TRANSBOUNDARY RIVERS

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Contents

1. Approaches to the Procedure of Funding by Countries of WMS Facilities on Transboundary Rivers

1. A Water Management System (WMS) on transboundary rivers is a complex system of water management projects and facilities, and their relationships dynamically progressing in conjunction with natural conditions already evolved and providing formation, allocation, delivery, and conservation of water resources.

The WMS main objective is to satisfy water demands of different sectors of economy and meet certain environmental requirements that guarantee sustainability of water management projects as a part of nature complex.

The WMS main functions may be described as follows:

- Formation of water resources, including over-year and seasonal regulation of natural flow, and water reproduction with the help of dams and reservoirs; relationships of surface and underground flow; storage of underground flow; hillside afforestation; impact on water formation zones; system of utilizing return water, and etc.

- Conservation of water resources (including monitoring water quality, setting and observance of ecological and sanitary releases, and requirements; agreed-upon polluter effluents, meeting natural needs of water bodies and water monitoring ground and return water; water use and treatment control). Basin, international, national, and intersectoral water allocation, including registering and observation system, water planning and delivery to customers right to water-use borders.

2. Economically, the WMS is a combination of projects, requiring, above all, precise and justified allocation of costs associated with interstate and intersectoral water use.

In its turn, to satisfy this condition particular O&M funding for WMS facilities is imperative. Funding is made taking into account both current conditions and optimum financing for effective operation of WMS facilities and water-use increased efficiency.

In what follows, issues addressed to financing approaches to joint use of WMS projects by the participant countries (and sectors, correspondingly) will be considered with the Naryn-Syr Darya system taken as an example.

The Basin Water Association (BVO) Syr Darya internationally manages the Naryn-Syr Darya system. Republic agencies and organizations manage regulating hydro complexes (reservoirs), territorial irrigation and energy projects.

3. As for capital assets, a WMS has available basic production assets and nonproductive assets with annual costs relating to operation.

Sectorally, basic production funds, and corresponding annual costs are allocated for the following main sectors:

- Hydro systems serving hydro power, irrigation, and other water users' needs;
- Irrigation (irrigated farming);
- Hydropower;
- Water supply and municipal economy;

- Recreation;
- Fish industry.

Basic production funds for multi-purpose works –regulating (irrigation and energy) hydro systems (reservoirs) - are presented in a book value of general-purpose, irrigation and energy projects, hydrometric stations and tracking systems for natural resources.

Basic production funds associated with irrigation are presented in a book value of irrigation projects (water diversion units, reservoirs and dams, main and interfarm canals, including large cascades of pump stations, nets of wells and other hydro facilities).

Basic production funds associated with hydropower are presented by a book value of hydropower plants[1].

Corresponding annual costs for the operation of capital assets are also presented.

Annual costs include:

- Salary for the basic serving staff;
- Maintenance of major and subsidiary facilities;
- Running and capital repair;
- Depreciation for renovation of capital funds

Total costs and their interstate and sector allocation for the Naryn-Syr Darya projects are given in Scheme 1.

4. WMS efficiency is governed by benefits from main sectors linked with use of basin water and land resources.

<u>In irrigation</u> the effect has been gained based on the activities of water and agricultural sectors and is expressed by net return received because of selling agricultural products.

<u>In hydropower</u> the effect has been gained as a result of electric power generated at particular hydropower plants (HPP), (cascades), and is expressed by net return received because of selling electric power.

Fundamental difference between effects in hydropower and irrigated farming is as follows:

A hydropower effect has been developed due to one alternating factor, that is water (quantity and head) passing through the HPP turbines;

Effect <u>in irrigated farming</u> has been reached due to water existing side by side with some current and alternating factors: farming technology, supply with fertilizers, chemicals and meliorants[2], labor inputs, and capital funds. According to professor Dukhovny and based on the USSR previous assessments [Dzevensky, Doctor of Science (Economics) and others] effect associated with water in the CA irrigated farming is 0.3, approximately.

In addition to a direct effect we should consider an entailing or secondary effect assessed by a share of irrigated farming in the efficiency of secondary and subsequent goods

[1] In this report, central hydro supply and treatment facilities are not considered because of their small share in the aggregate water use, and due to their belonging to a nation.

[2] Land improver

(fiber, yarn, fabric, flour, etc.). For our calculations, based on the same studies, such effect may be assessed by the coefficient 1.5.

Yet, appraising the affects associated with entire WMS activities we should take into account losses and damages resulted from wrong, unilateral “egoistic” water uses that meet narrow-branch or national interests and inflict damage on nature, downstream countries, and other.

From these positions while assessing damage to irrigated farming we should take into consideration secondary entailing effect of process industries and the fact that the direct effect may not be gained.

5. Different forms of project ownership in the zone of WMS activities are available:

- Interstate ownership, associated with the projects transferred by the countries to a temporary management onto the balance of the Basin Water Associations;
- State ownership, i.e. ownership of projects being on the balance of Republic water and energy administrations (Minselvodkhozes[3], State Water Committees, Minenergos[4], Goskomprirodas[5], Hydrometeoservices, etc);
- Stock ownership, associated with the projects being in ownership of stock societies and companies.

If to consider the Naryn Syr Darya WMS, ownership was identified as follows:

- Interstate ownership, associated with the projects being on the balance of the BVO Syr Darya;
- State ownership, i.e. ownership of projects being on the balance of Republic water management and energy administrations.

1) In Uzbekistan:

- Territorial main and interfarm irrigation systems and facilities (Minselvodkhoz);
- Andizhan Hydro System (Minselvodkhoz);
- Charvak Hydro System (Minenergo);
- Chirchik HPP cascade (Minenergo)

2) In Kyrgyzstan:

- Territorial main and interfarm irrigation systems and facilities (Minselvodkhoz)

3) In Tajikistan:

- Territorial main and interfarm irrigation systems and facilities (Committee on Water Resources)

4) In Kazakhstan:

- Territorial main and interfarm irrigation systems and facilities (Committee on Water Resources)

[3] Ministries of Agriculture and Water Management
[4] Ministries of Energy
[5] State Committees on Nature Protection

Stock ownership is represented by the projects whose owners are stock societies and companies:

a) in Kyrgyzstan:

- Toktogul Hydro System (SC Kyrgyzenergoholding);
- HPP Naryn Cascade (SC Kyrgyzenergoholding)

b) in Tajikistan:

- Kairakum Hydro System (SHC Barki Totchik);
- Interfarm systems

c) in Kazakhstan:

- Chardara Hydro System (SC Kazenergo);
- Part of interfarm system (Water Users' Association).

6. According to WMS categories of ownership principles of capital investments and annual operation costs have been also determined.

- WMS international projects being under the BVO jurisdiction are funded from state budgets of the countries sharing water uses of the basin.

- Sharing principle to fund BVO has been specified by interstate agreements, which consider proportional funds based on water amounts delivered to the countries.

- WMS territorial projects being under the jurisdiction of water and energy administrations of the countries are funded from national budgets.

- WMS projects being under the jurisdiction of stock companies are funded from their own funds.

Table 1 shows costs and their allocation among countries, projects and by ownership for the Naryn –Syr Darya system.

7. To regulate relationships for funding and allocating costs associated with joint use of transboundary water resources an international agreement of the Central Asian countries has been proposed and approved by three Governments (Kazakhstan, Tajikistan, and Uzbekistan) (17 June 1997). The agreement regulated procedure of funding and allocation of costs for BVO being considered as an ICWC structural division.

In compliance with the Agreement, each country has to pay its own funding share from the country budget based on interest to receive necessary water amounts from the basin. The funding means are allocated for construction, reconstruction and operation of the BVO facilities.

To maintain interests of the countries while sharing water use from hydro complexes in terms of their operation in irrigation and energy release modes principles of mutual compensations among the countries have been agreed upon.

Following those principles:

- The Kyrgyz Republic to keep to the set irrigation releases transfers electric power to Kazakhstan and Uzbekistan during the growing season;
- The Republic of Uzbekistan provides immediate power and natural gas deliveries as a compensation for the Kyrgyz power in agreed volumes and schedules, and supplies fuel oil. The calculation terms, according to the Agreement, are retained between the Governments of Uzbekistan and Kyrgyzstan.

- The Republic of Kazakhstan delivers electric power to the Talas oblast, as a compensation for the electric power delivered by Kyrgyzstan, and the remained power is compensated by the Karaganda coal in agreed amounts and time;

- Mutual settlements are made on terms of agreement between the Republics of Kyrgyzstan and Uzbekistan and Republics of Kazakhstan and Kyrgyzstan. However, it should be taken into consideration that not only explicit barter but also implicit departmental interests are meant there.

For instance, Kazakhstan receives hydropower at the price of summer selling for Kazakhstan and Uzbekistan, for which 400%-500% rate of return has been put. As a response measure the Republics of Uzbekistan and Kazkhstan, in their turn, raise prices for gas and other fuel deliveries, bringing them nearer to the world prices.

8. Study of the WMS funding status proves that proposals given in world-wide practice for interstate and intersector cost and benefit allocation are targeted at making calculations on the design stage for the projects to be constructed. The most acceptable of all recommended approaches is a much-used method of calculation of “separable and joint costs”.

The recommended method proposes:

- to estimate cost of an energy portion of a complex of facilities;
- to estimate cost of an irrigation part of a complex of facilities;
- to appraise balance of cost – non-separable costs (for shared energy and irrigation projects), and they are allocated among the complex components.

Proposals to allocate only annual costs associated with joint use of regulating hydro multi-purpose facilities (reservoirs) might also be found.

EPIC, for instance, while allocating annual O&M costs, recommends first “to allocate costs which can be associated with a single purpose or user…” and they call them “separable costs”. Next, with the help of some method the costs “which cannot be associated with a single purpose or user are allocated to the purposes or users on the basis of some agreed-upon rules”. (“Options Analysis of the Operation of the Toktogul Reservoir”, Almaty, John E. Keith and Daene C. McKinney). Several of O&M cost allocation ways have been offered:

- Entirely by one of the participating countries;
- Equally among all users;
- Proportional sharing;
- On demand;
- On an economic basis.

9. The comprehensive analysis of available approaches to cost and benefit allocation among the participants of joint use of the WMS facilities shows:

- No generally accepted methods of allocation of O&M costs and benefits for jointly used systems have been developed;

- A major part of methodical approaches to cost and benefit allocation for the indicated projects are intended for calculations when designing new facilities; Recommended approaches to O&M cost and benefit allocation for operating systems, and especially for the WMS, as a whole, require profound correction;

- Development of new principles and approaches to the funding matter of the WMS facilities is required with consideration of interstate and intersector cost and benefit allocation. Corrected approaches to both funding and allocation of costs and benefits for hydro systems are also essential. In the process, a binding condition is to take into account specific economic, legal and social factors inherent to the Central Asian countries due to their independence and transition to market relations.

For the advancement of the issue we have developed and propose approaches to funding, allocation of costs and benefits in the process of a joint operation of WMS complexes by the countries:

Option 1: Determination and allocation of costs and benefits under the interstate and intersector use of the entire complex of facilities functioning on transboundary rivers; consistent to the principle of effects proportionate to costs, or costs proportionate to effects.

Option 2: Allocation of costs and benefits gained from joint operation by sectors of entire irrigation and energy hydro systems proportionate to the effects (is identical to hydro systems only).

Option 3: Method of allocation of O&M costs of the Toktogul hydropower system between energy and irrigation sectors based on regulated flow amounts and effects obtained in the sectors.

Below, we describe foundation principles built into the recommended approaches and give associate calculations for all options. In the Appendix, we offer a system of technical and economic indices developed to determine, calculate and allocate costs and benefits associated with joint use of WMS facilities.

2. Recommended Approaches

To The Procedure Of Funding And Allocation Of Costs And Benefits Under The Joint Operation Of Water Complexes On Transboundary Rivers By The Countries

To improve available methodological developments, we have proposed the options of approaches to determine and allocate costs and benefits under the joint interstate and intersector use of the water complex facilities and carried out preliminary calculations.

Option 1 **Determination and allocation of costs and benefits under the interstate and intersector joint use of the entire complex of facilities functioning on transboundary rivers within the Naryn-Syr Darya water complex in general is proportionate to the equality of benefits from water management.**

Determining incurred costs, costs of all water and energy facilities operated at the interstate and state level are taken into account in this option:

- basin water associations;
- complex regulating hydrosystems (carry-over storages);
- state (territorial) water management agencies and objects;
- hydropower plants (cascades of hydropower plants).

Determining effects resulting from the use of water resources of water management complex, the total effect (in the form of net income), effects of irrigation and hydroenergy (owing to the power generation by hydropower plants) are defined.

General and sector determination and allocation of costs associated with the joint use of water facilities is shown on Diagram 1.

Allocation of costs between the states participating in the use of water facilities is carried out in the similar way.

Under the adopted scheme of cost allocation for the Naryn-Syr Darya water complex, these costs have been adopted and allocated for the entire water management complex and each sector and republic in respect to the following objects:

- Basin Water Management Association BVO Syr Darya exploiting interstate water facilities. Costs are determined for BVO as a whole and for each republic according to their share parts in total costs.

- Complex hydrosystems (carry-over storages) on transboundary rivers serving irrigation and energy.

Costs are determined for the following objects:

- Toktogul hydrosystem (Kyrgyzstan);

- Andizhan hydrosystem (Uzbekistan);
- Charvak hydrosystem (Uzbekistan);
- Chardara hydrosystem (Kazakhstan);
- Kairakkum hydrosystem (Tajikistan).

- Water management authorities of the republics (Ministries of Agriculture, State Committees) operating the state irrigation facilities in the influence area of the Naryn-Syr Darya water complex of 4 countries (Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan).

- Hydropower plants, HPPs, (cascades of hydropower plants) on the rivers of the Naryn-Syr Darya water complex (except for HPPs being components of the complex hydrosystems. The costs of these complex hydrosystems are taken into account in their composition).

In accordance with the system of technical and economic indicators, which we developed, determining the types of costs associated with the operation of facilities of the Naryn-Syr Darya water complex, we showed calculations concerning the following cost categories:

- Cost of fixed assets of the water complex facilities.
- Annual costs associated with operation of the water complex facilities, including maintenance of staff and facilities, routine and capital repair, and depreciation to renovate the fixed assets.
- Discounted costs associated with operation of the water complex facilities.

Determining and calculating the indicators specified, a series of conditions is met:

- We have taken into consideration, that at present all water management organizations receive financing from the state budget (BVO, water facilities of Ministries of Agriculture, part of complex hydrosystems, part of hydropower plants and their production activity do not provide direct benefits).

- The data under use regarding the costs of Ministries of Agriculture and Water Management, Uzbekistan and Tajikistan, are taken only in the part related to the Naryn-Syr Darya water complex. The data regarding Kyrgyzstan completely relate to the water complex. The data regarding Kazakhstan are taken within water costs of the Kzyl-Orda oblast and 4 rayons of the South Kazakhstan oblast.

- The information used in cost calculations is represented by the data of the economic block of the WARMIS database, which was carried out by national groups.

Below, Table 1 shows major cost indicators in respect to the entire Naryn-Syr Darya water complex and the component facilities thereof.

The analysis of data shown in Table 1 allows pointing out the following:

- In the total cost of fixed assets regarding the facilities of the Naryn-Syr Darya water complex, the most specific weight belongs to the fixed assets of complex hydrosystems (56.6%) and the funds of the republic water authorities (31.5%).

As to the sector allocation of the fixed assets costs for the entire water complex, 60.9% of the total cost relates to the irrigation facilities and 39.1% to the energy facilities.

The situation of annual costs associated with the operation of water facilities is somewhat different.

With the specific weight of costs associated with the operation of complex hydrosystems accounting for 29.9% of the total costs, the costs of operating the republic facilities are 53.9%.

As to the sector allocation of costs, irrigation costs are 70.5% and energy costs are 29.5% of the total.

The dimensions of cost of the water complex fixed assets and costs associated with the operation of these assets formed the value and relationship of discounted costs:
64.5% for irrigation and 35.5% for energy of the total discounted costs.

Table 2 shows cost indicators characterizing full annual operation costs and costs in the context of republics, facilities and sectors jointly using the water complex.

Table 3 shows specific participation in the joint costs associated with shared operation of the Naryn-Syr Darya water complex for each republic and sector.

Table 3

Allocation of the Joint Costs Associated with Shared Operation of the Facilities of the Naryn-Syr Darya Water Complex (percentage)

Republic	**Cost of Fixed Assets of Water Facilities**			**Annual Operational Costs of Fixed Assets of Water Complex**			**Discounted Costs of Water Complex**		
	Total	**Related to Irrigation**	**Related to Energy**	**Total**	**Related to Irrigation**	**Related to Energy**	**Total**	**Related to Irrigation**	**Related to Energy**
Uzbekistan	40.3	49.9	25.3	44.3	50.8	29.0	43.0	50.4	28.9
Kazakhstan	10.7	15.0	4.1	14.8	19.8	2.9	12.5	17.5	3.5
Kyrgyzstan	37.8	21.4	63.2	29.7	15.9	63.0	33.5	18.6	60.5
Tajikistan	11.2	13.7	7.4	11.2	13.5	5.1	11.0	13.5	7.1
Water Complex	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Data shown before in Tables 2 and 3 (percentage) characterize the degree of share participation of individual countries jointly using the irrigation and energy potential of the Naryn-Syr Darya water complex and the allocation of the specified costs between irrigation and energy.

The analysis shows that regarding general indicators of the fixed assets costs, annual costs and discounted costs, Uzbekistan (40.3%, 44.3%, 43.0% respectively) and Kyrgyzstan (37.8%, 29.7%, 33.5% respectively) account for the major part of the indicators.

However, consideration of cost indicators by sectors of economy shows that regarding specific weight of the fixed assets cost, annual costs and discounted costs associated with energy, Kyrgyzstan has the highest specific weight (63.2%, 63% and 60.5% respectively).

Effects of sectors are determined in accordance with the proposed method of calculating effects resulted from the shared use of the Naryn-Syr Darya water complex facilities. They are expressed through the net income of irrigation and energy.

Net income of irrigation is determined based on the WUFMAS database as an average productivity indicator of main crops.

Total net income of irrigated agriculture in the influence zone of the Naryn-Syr Darya water complex is determined to be 237.8 $/ha.

Given share influence of water factor (coefficient 0.3) and the effect of adjoint sectors (coefficient 1.5), average net income accounts for 107 $/ha.

Total net income of irrigated agriculture in the influence zone of the Naryn-Syr Darya water complex (1,915,000 hectares) accounts for $205.3 million.

The allocation of net income of irrigated agriculture among the republics is as follows:

Uzbekistan – $81.8 million.
Kazakhstan - $73.7 million.
Kyrgyzstan - $23.8 million.
Tajikistan - $26.0 million.

Calculation of net income of irrigated agriculture received by the countries jointly using the facilities of the Naryn-Syr Darya water complex is shown in the following Table.

Calculation of Net Income of Irrigation in the Influence Zone of Flow Regulation for the Naryn-Syr Darya Water Complex in the Context of Republics

No.	Republic	Average Net Income of Irrigation per 1 ha $/ha	Average Net Income of Irrigation, Given Water Factor and Effect of Adjoint Sectors (coefficient 0.45) $/ha	Irrigated Area in the Influence Zone of Flow Regulation thousand ha	Net Income of Irrigation $ million
1	Uzbekistan	173.8	78.2	1046	81.8
2	Kazakhstan	334	150.5	490	73.7
3	Kyrgyzstan	259	116.7	204	23.8
4	Tajikistan	330	148.6	175	26
	TOTAL of Water Complex	**237.8**	**107**	**1915**	**205.3**

As the Table shows, the productivity of irrigated lands varies considerably by the republics.

Maximum net income of irrigation is received in Kazakhstan (334 $/ha) and Tajikistan (330 $/ha). Kyrgyzstan have used irrigated lands with less productivity (259 $/ha). Uzbekistan has obtained minimum net income (173.8 $/ha).

Net income of energy is determined according to the adopted methods of its calculation.

To calculate total net income of the entire water complex and of each republic served by the hydropower plants of the water complex, average data on the cost of gross output, costs and net income of the hydropower plant cascades are adopted.

Dimensions of net income of hydroenergy for the cascades of the Naryn-Syr Darya water complex are $450.9 million, including those for republics:

Kyrgyzstan – $274.3 million.
Uzbekistan – $140.4 million.
Kazakhstan – $15.5 million.
Tajikistan - $20.7 million.

Calculations on incurred costs and derived benefits from the shared use of the Naryn-Syr Darya water complex allowed determining the ratio of net income and incurred costs, both for sectors (irrigated agriculture and hydroenergy) and republics participating in the operation of water complex facilities.

Ratio of net income and incurred costs is considered separately in comparison with discounted costs and annual operation costs (see the following Table).

Table

Calculation of Net Income of Irrigation in the Influence Zone of the Naryn-Syr Darya Water Complex in the Context of Republics

No.	Sectors	Net Income of Sector $ million	Discounted Costs of Sector $ million	Ratio of Net Income and Sector Discounted Costs $ million	Ratio of Net Income and Sector Annual Costs, $ million
1	Irrigated Agriculture	205.3	944.9	0.22	0.42
2	Hydroenergy	450.9	519.8	0.88	2.23
	Total of Water Complex	**656.2**	**1464.7**	**0.45**	**0.97**

Data of Table 7 show that average sector net income per $1 of discounted costs and annual costs amounts to:

for irrigated agriculture: $0.22 and $0.42 respectively;
for energy: $0.88 and $2.23 respectively;
for the entire water complex: $0.45 and $0.97 respectively.

Data of the above Table are illustrative. They characterize the ratio of net income and total annual costs associated with operation of the entire water complex, in the contexts of sectors and countries:

– Net income of irrigated agriculture doesn't cover costs of water production in all republics;
– Net income of hydroenergy in all republics considerably exceeds annual costs of the energy facilities operation.

Given total negative effect of $27.8 million for the entire water complex, only Kyrgyzstan receives net income exceeding incurred costs by $94 million.

To define the ratio of effects received by the countries, which jointly use the potential of the Naryn-Syr Darya water complex, and costs incurred by these countries, calculation of a proportion between the effects received and the costs incurred has been carried out. It has been carried out under the conditions of single profitability rate for fixed assets, annual costs and discounted costs.

Tables 7, 8, 9 show indicators resulted from calculations.
The calculations, which were carried out, showed:

<u>Regarding fixed assets:</u>
Given single profitability rate of 10.36% for fixed assets of the water complex, the cost of fixed assets of Uzbekistan and Tajikistan exceeds the cost required to obtain the given effect under the specified profitability by $410 and $257.5 million respectively.

At the same time, the cost of fixed assets in Kazakhstan and Kyrgyzstan under the same conditions lower than the required cost by $180.3 and $485 million respectively.

<u>Regarding annual costs:</u>
Given single profitability rate of 95.9% for annual operation costs of the water complex facilities, the size of costs required for the given effect under the specified profitability exceeds actual costs by $71.6 million for Uzbekistan, by $27.2 million for Tajikistan. It is lower than the required costs on Kyrgyzstan amounting to $107.6 million.

<u>Regarding discounted costs:</u>
Given single profitability rate of 44.8% for discounted costs, discounted costs required for the given effect under the specified profitability exceeds by $134.6 million for Uzbekistan and by $56.4 million for Tajikistan. These discounted lower than the required discounted costs by $16.0 million for Kazakhstan and $175.1 million for Kyrgyzstan.

<u>Option 2.</u> Allocation of Costs and Benefits Gained from Joint Operation by Sectors of Entire Irrigation and Energy Hydro Systems (Consistent to the Principle of Effects Proportionate to the Costs, and Reverse, Costs Proportionate to the Effects)

The Option considers total and sector costs for hydro systems of the countries and aggregate and sector effects, the latter are compared with the costs and they are proportionally divided.

The following Haryn-Syr Darya hydro complexes have been appointed for calculations:

- Andizhan Hydro System (Uzbekistan);
- Charvak Hydro System (Uzbekistan);
- Chardara Hydro System (Kazakhstan);
- Toktogul Hydro System (Kyrgyzstan);
- Kairakkum Hydro System (Tajikistan)

The indices computed in Option 1 are used as initial data for determination, calculation and allocation of costs and benefits for each hydro system and each country:

- discounted costs associated with operation of water complex facilities and allocated for irrigation and energy;
- annual costs associated with water complex facilities , including costs for maintenance, repairs and depreciation of capital assets, and allocated for irrigation and energy;
- Total net return from joint use of hydro systems with its breakdown to net returns from irrigation and energy.

Table 1 presents total cost indices for the Naryn-Syr Darya hydro complexes.

To determine productivity of sector costs made while operating hydro systems for gaining a general effect we used the method, which recommended setting off sector net return proportionate to the costs, using the expression:

$$\frac{\times \text{Ä}_{\text{îòð.ã/óç}}}{\text{Ï}_{\text{ð.îòð.ã/óç.}} + \text{Ï}_{\text{ð.îòð.ýëåì.}}} \; \text{õ} \; \text{Ï}_{\text{ð.îòð.ã/óçëà}} \qquad (1)$$

For irrigation:

$$\frac{\times \text{Ä}_{\text{îð.ã/óç}}}{\text{Ï}_{\text{ð.îð.ã/óç.}} + \text{Ï}_{\text{ð.îð.Ì ÑÂÕ}} + \text{Ï}_{\text{ð.îð.ÁÂÎ}}} \; \text{õ} \; \text{Ï}_{\text{ð.îð.ã/óç.}} \qquad (2)$$

For energetics:

$$\frac{\times \text{Ä}_{\text{ýí.ã/óç}}}{\text{Ï}_{\text{ð.ýí..ã/óç.}} + \text{Ï}_{\text{ð.ýí.ÃÝÑ}}} \; \text{õ} \; \text{Ï}_{\text{ð.ýí.ã/óç.}} \qquad (3)$$

Where $\times \text{Ä}_{\text{îòð.ã/óç}}$ -Total sector net return attributed to the hydro system, millions of $;

$\text{Ï}_{\text{ð.îòð.ã/óç}}$ -Sector discounted costs attributed to the hydro system, millions of $;

$\text{Ï}_{\text{ð.îòð.ýëåì.}}$- Sector discounted costs attributed to the WMS complex of elements, millions of $;

$\times \text{Ä}_{\text{îð.ã/óç}}$ - Net return from irrigation attributed to the hydro system, millions of $;

$\text{Ï}_{\text{ð.îð.ã/óç.}}$ – Irrigation discounted costs attributed to the hydro system, millions of $;

$\text{Ï}_{\text{ð.îð. ÌÑÂÕ}}$ - Irrigation discounted costs attributed to the republic water management departments, millions of $;

$\text{Ï}_{\text{ð.îð.ÁÂÎ}}$ - Irrigation discounted costs attributed to the BVOs, millions of $;

$\text{×ä}_{\text{ýí.ã/óç}}$ - Net return from energetics attributed to the hydro system, millions of $;

$\text{Ï}_{\text{ð.ýí..ã/óç.}}$ – Energy discounted costs attributed to the hydro system, millions of $;

$\text{Ï}_{\text{ð.ýí.ÃÝÑ}}$ - energy discounted costs attributed to the HPPs (cascades), millions of $.

Below are the calculations made for the WMS hydro complexes of the countries:

<u>Sharing effect of hydro systems from irrigation:</u>

Andizhan Hydro System

Charvak Hydro System (Uzbekistan)

$$\frac{181.8}{100.4+365.2+10.6} \text{ õ } 100.4 = \$\ 38.3$$

million;

Chardara Hydro System (Kazakhstan)

$$\frac{163.7}{39.8+116.6+8.8} \text{ õ } 39.8 = \$\ 39.4$$

million;

Toktogul Hydro System (Kyrgyzstan)

$$\frac{52.8}{117.5+58.0+0.1} \text{ õ } 117.5 = \$\ 35.3$$

million;

Kairakkum Hydro System (Tajikistan)

$$\frac{57.8}{58.1+68.3+1.5} \text{ õ } 58.1 = \$\ 26.2$$

million;

Table 2 shows allocation of sharing net return from irrigation among the elements of the Naryn- Syr Darya WMS according to the discounted costs.

Analysis of the Table 2 data shows that in the total effect from irrigation, produced from joint use of hydro complexes, share of those hydro systems made up - 33.4 % for the WMS; share of republic water management departments - 64.3 %; and the BVO Syr Darya’s share constituted 2.3 %.

For different hydro systems the share of net return from irrigation attributed to the hydro systems ranges from 21 % (Uzbekistan) to 66.9 % (Kyrgyzstan).

Sharing effect of hydro systems from energetics:

Andizhan Hydro System
Charvak Hydro System (Uzbekistan) 140.4
-------------------- õ 68.3 = $ 71.4 million;
68.3+66.1

Chardara Hydro System (Kazakhstan) 15.5
------------ õ 17.9 = $ 15.5 million;
17.9

Toktogul Hydro System (Kyrgyzstan) 274.3
-------------------- õ 200.2 = $ 174.5
million;
200.2+114.5

Kairakkum Hydro System (Tajikistan) 20.7
------------ õ 32.8 = $ 20.7 million;
32.8

Table 3 presents allocation of sharing net return from energetics among the Naryn-Syr Darya WMS elements.

The tabular data show that the net return share from energetics attributed to the hydro systems makes up 63.8 % for the WMS, 50.8 % for Uzbekistan and 63.6 % for Kyrgyzstan.

Share of the effect from energetics attributed to the Chardara and Kairakkum hydro systems constitutes 100 %.

Option 3

Method of Allocating O&M Costs of the Toktogul Hydrosystem between Energy and Irrigation Depending on Volumes of Regulated Flow and Effects of Sectors of Economy

1. General Principles

1.1 Allocation of Costs Based on the Principle of Evaluating Effects from Flow Regulation in Energy and Irrigated Agriculture

- O&M costs of the Toktogul Hydrosystem **(Ç)** are prorated to the effects received in hydroenergy **($\text{Ý}_{\text{ýí}}$)** and irrigated agriculture **($\text{Ý}_{\text{èð}}$)** from use of volumes of regulated flow.

- Total volume of the flow regulated by the Toktogul Reservoir **($W_{\text{ðåã}}$)** comprises (as the algebraic sum of) the volumes of reservoir storage **($W_{\text{íàï}}$)** and drawdown **($W_{\text{ñðàá}}$).** The volumes of reservoir storage correspond to positive values of volumes of the regulated flow. The volumes of reservoir drawdown correspond to negative values.

- The Toktogul Reservoir is drawn down to meet the demands of hydroenergy and irrigated agriculture (**$W_{\text{ñðàá.á-èð}}$**). The volumes of this drawdown (**$W_{\text{ñðàá.ýí}}$**) as compared with natural flow of the Naryn River **($W_{\text{á}}$)** are the values, which are used to evaluate the effects of flow regulation in energy **($\text{Ý}_{\text{ýí}}$)** and irrigated agriculture **($\text{Ý}_{\text{èð}}$)**.

- The volumes of the flow regulated by the Toktogul Reservoir for energy **($W_{\text{ðåã.á-ýí}}$)** and irrigation **($W_{\text{ðåã.á-èð}}$)** are determined through comparing the water flows required for hydropower **($W_{\text{ýí}}$)** and irrigated agriculture **($W_{\text{èð}}$)** with the natural flow **($W_{\text{á}}$)** of the Naryn River.

- Water demands of irrigated agriculture **($W_{\text{èð}}$)** for water releases from the Toktogul Reservoir are determined proceeding from water losses and the allowed amounts of water diversion from the Syr Darya River and the Naryn River.

- Water demands of hydroenergy **($W_{\text{ýí}}$)** to the Naryn River flow are determined based on the load required from the Naryn Cascade of hydropower stations **($N_{\text{êàñê}}$)** and total average water head **($H_{\text{êàñê}}$)** of 5 stations (Òîktogul, Êurpsai, Òàshkumyr, Shamoldysai, and Uchkurgan).

- Effects of irrigated agriculture **($\text{Ý}_{\text{èð}}$)**, which result from the regulation of flow by the Toktogul Reservoir, are determined based on the volumes of reservoir drawdown for irrigation (**$W_{\text{ñðàá.á-èð}}$**) and the productivity of 1 m^3 of irrigation water (**$\text{Ï}_{\text{è ð}}$**).

- Effects of hydroenergy **($\text{Ý}_{\text{ýí}}$),** which result from the regulation of flow by the Toktogul Hydrosystem, are determined based on the amount of hydropower **($\text{Å}_{\text{ðåã}}$)** generated by the Naryn Cascade of hydropower plants ($\mathbf{W}_{\text{ñðàá.á-ýí}}$), cost of hydropower **($\mathbf{Ñ}_{\text{ýí}}$),** and its cost (**Ö**). This relates to the hydropower generated using the volume of the reservoir drawdown ($\mathbf{W}_{\text{ñðàá.ýí}}$) against the natural flow.

- The cost of electric power (**Ö**) is determined taking into account opportunities to sell it at the home **($\mathbf{Ö}_{\text{âíóò}}$)** and foreign **($\mathbf{Ö}_{\text{âíåø}}$)** markets. The supply of electric power to the foreign market can amount only to 20 % of the total power generation.

1.2 Allocation of Costs Based on the Principle of Evaluating Volumes and Cost of the Flow Regulated by the Toktogul Hydrosystem

- Total O&M costs of the Toktogul Hydrosystem **(Ç)** include the costs of reservoir storage **($\mathbf{Ç}_{\text{íàï}}$),** while accumulating river flow for multi-year regulation, and the costs of seasonal drawdown **($\mathbf{Ç}_{\text{ñðàá}}$).** The seasonal drawdown of reservoir is carried out in addition to the natural river flow.
- The allocation of total drawdown costs between hydroenergy and irrigation is carried out prorated to the volumes of drawdown separately for the energy **($\mathbf{Ç}_{\text{ñðàá.ýí}}$)** mode and the irrigation **($\mathbf{Ç}_{\text{ñðàá.èð}}$)** mode.
- The regulation cost **($\mathbf{Ö}_{\text{ðåã}}$)** is a value of specific costs associated with one unit of volume of the regulated flow.

2. Calculation Relationships

2.1 Allocation of Costs Based on the Principle of Evaluating Effects from Flow Regulation in Energy and Irrigated Agriculture

The volumes of the flow regulated by the Toktogul Reservoir are computed for each month for the energy and irrigation modes:

$\mathbf{W}_{\text{ðåã.á-ýí}} = \mathbf{W}_{\text{á}} - \mathbf{W}_{\text{òð. ýí}}$, million m^3.......................... **(2.1.1),**
$\mathbf{W}_{\text{ðåã.á-èð}} = \mathbf{W}_{\text{á}} - \mathbf{W}_{\text{òð. èð}}$, million m^3.......................... **(2.1.2),**

where: $\mathbf{W}_{\text{á}}$ - natural flow, i.e. inflow to the Òîktogul Reservoir, million m^3,
$\mathbf{W}_{\text{òð. ýí}}$ – demands of hydroenergy for water releases from the Toktogul Hydrosystem, million m^3.
$\mathbf{W}_{\text{òð. èð}}$ - demands of irrigated agriculture for water releases from the Toktogul Hydrosystem, million m^3.

The demanded flow ($\mathbf{W}_{\text{òð. ýí}}$) is defined by the water flow, which passes through hydropower plant ($\mathbf{Q}_{\text{ýí}}$):

$\mathbf{W}_{\text{ýí}} = \mathbf{Q}_{\text{ýí}}\ \mathbf{m10^{-6}}$, million m^3/month........................**(2.1.3)**
$\mathbf{Q}_{\text{ýí}} = \mathbf{102\ N}_{\text{êàñê}} / \mathbf{H}_{\text{êàñê}}\ \eta$, m^3/second........................**(2.1.4)**

where: η_{i} = 0,85 - efficiency factor of the Naryn Cascade of hydropower plants (HPPs);

$\mathbf{H_{\hat{e}\grave{a}\tilde{n}\hat{e}}}$ = 340 m – total water head of the Naryn Cascade of HPPs;
$\mathbf{N_{\hat{e}\grave{a}\tilde{n}\hat{e}}}$ – required average monthly power load of the Naryn Cascade of HPPs, Ì W.
m – number of seconds in a month.

Volumes of reservoir drawdown:

$\mathbf{W_{\tilde{n}\eth\grave{a}\acute{a}.\,\acute{y}\acute{i}} = min\,[0, W_{\eth\tilde{a}\tilde{a}.\acute{a}.-\acute{y}\acute{i}.}],}$ million m^3 ....**(2.1.5)**
$\mathbf{W_{\tilde{n}\eth\grave{a}\acute{a}.\,\grave{e}\eth} = min\,[0, W_{\eth\tilde{a}\tilde{a}.\acute{a}.-\grave{e}\eth.}],}$ million m^3 ....**(2.1.6).**

Effects of flow regulation in hydroenergy sector:

$\mathbf{\acute{Y}_{\acute{y}\acute{i}.} = E_{\eth\tilde{a}\tilde{a}}\,(\ddot{O} - \tilde{N}_{\acute{y}\acute{i}}),}$ million \$................. **(2.1.7)**

where: $\mathbf{E_{\eth\tilde{a}\tilde{a}}}$ power generation by the Naryn Cascade of HPPs based on the drawdown volume of the Toktogul reservoir, million. kWh;
$\mathbf{\tilde{N}_{\acute{y}\acute{i}}}$ ñost of the electric power of the Cascade, \$/kWh;
Ö cost of electric power, which is determined taking into account the opportunity to sell it at the home and foreign markets, \$/kWh. The supply of electric power to the foreign market can amount only to 20 % of the total power generation ($\mathbf{\mathring{A}_{\hat{e}\grave{a}\tilde{n}\hat{e}}}$). Therefore, we determine the cost of electric power by the following formula:

$\mathbf{\ddot{O} = (0.2\,\mathring{A}_{\hat{e}\grave{a}\tilde{n}\hat{e}}\,\ddot{O}_{\hat{a}\acute{i}\mathring{a}\o} + 0.8\,\mathring{A}_{\hat{e}\grave{a}\tilde{n}\hat{e}}\,\ddot{O}_{\hat{a}\acute{i}\acute{o}\grave{o}\eth}) / \mathring{A}_{\hat{e}\grave{a}\tilde{n}\hat{e}}}$**……… (2.1.8)**
$\mathbf{\ddot{O}_{\hat{a}\acute{i}\acute{o}\grave{o}\eth}}$ – electric power tariff within the Kyrgyz Republic, [\$/kWh]
$\mathbf{\ddot{O}_{\hat{a}\acute{i}\acute{o}\grave{o}\eth}}$ = \$0.0073 / kWh
$\mathbf{\ddot{O}_{\hat{a}\acute{i}\mathring{a}\o}}$ – tariff on the electric power, which the Kyrgyz Republic supplies to other republics, [\$/kWh]
$\mathbf{\ddot{O}_{\hat{a}\acute{i}\mathring{a}\o}}$ = \$0.04 / kWh
During a year, the cost of electric power does not change. It equals **Ö = \$0.0138 / kWh.**

The cost of electric power generated by the Naryn Cascade of HPPs:

$\mathbf{C_{\acute{y}\acute{i}} = \lambda \times C_{\acute{y}\acute{i}.91.}}$, \$/kWh ....**(2.1.9)**,

$\mathbf{\lambda = 1{,}04^{n}}$ ....**(2.1.10),**

where: $\mathbf{C_{\acute{y}\acute{i}\ 91}}$ – cost at the level of 1991, \$/kWh (calculated at the exchange rate of rubles to US dollars);
λ - inflation coefficient;
n – number of years = 8,

Power generation of the Naryn Cascade of HPPs, when the drawdown volumes of Toktogul Hydrosystem are used:

$\mathbf{E_{\eth\tilde{a}\tilde{a}} = -\,(W_{\tilde{n}\eth\grave{a}\acute{a}.\acute{a}.-\acute{y}\acute{i}}) \times T_{i.} \times H_{\hat{e}\grave{a}\tilde{n}\hat{e}} \times \eta\ / (k \times 102 \times 1000)}$, million kWh ....**(2.1.11)** where: **k** coefficient for converting monthly flow volumes (million.m^3/month) into average monthly water flow (m^3/second),

$\mathbf{H}_{\text{êàñê}}$ total operating head of the Naryn Cascade of HPPs,

η = 0,85 – average coefficient of efficiency of the Cascade of HPPs,

$\mathbf{T}_{\mathbf{i}}$ number of hours in a month, when capacity is used.

Effects of flow regulation in irrigated agriculture:

$\mathbf{Ý}_{\text{èð.ðåã}}$ **=** $\mathbf{Ï}_{\text{èð}} \times \mathbf{W}_{\text{ñðàá.á.-èð}}$**,** million $................ **(2.1.12)**

where: $\mathbf{Ï}_{\text{èð}}$ **= $0.013 / ì^3.–** productivity of irrigation water

2.2. Allocation of Costs Based on the Principle of Evaluating Volumes and Cost of the Flow Regulated by the Toktogul Hydrosystem

The cost of seasonal flow regulation, where the annual value of $\mathbf{W}_{\text{ð ãã}}$ **= 0**, is determined as follows:

$\mathbf{Ö}_{\text{ð ãã. ñåç}}$ **=** $\mathbf{Ç}_{\text{ð ãã}}$**/ W** $_{\text{ñðàá.}}$ \$/m^3...................................**(2.2.1)**

where: $\mathbf{Ç}_{\text{ð ãã}}$ – total annual costs associated with the flow regulated by the Toktogul Hydrosystem are accepted as equal to 37.8 million. $;

$\mathbf{W}_{\text{ñðàá}}$ – drawdown volume of the Toktogul Reservoir, million m^3

Allocation of costs between energy and irrigation **(**$\mathbf{Ç}_{\text{ñðàá.èð}}$**,** $\mathbf{Ç}_{\text{ñðàá.ýí}}$**)** is determined through cost of seasonal regulation $\mathbf{Ö}_{\text{ð ãã.ñåç}}$ and corresponding values of the drawdown volume:

$\mathbf{Ç}_{\text{ñðàá. ýí}}$ **=** $\mathbf{Ö}_{\text{ð ãã. ñåç}}$ **x** $\mathbf{W}_{\text{ñðàá.ýí}}$**,** million $......................**(2.2.2)**

$\mathbf{Ç}_{\text{ñðàá. èð}}$ **=** $\mathbf{Ö}_{\text{ð ãã. ñåç}}$ **x** $\mathbf{W}_{\text{ñðàá. èð}}$**,** million $ **(2.2.3)**

The cost of multi-year flow regulation, when annual $\mathbf{W}_{\text{ð ãã}}$ **> 0** and the reservoir storage is considered for the entire year $\mathbf{W}_{\text{íàï . ãîä}}$**,** is determined as follows:

$\mathbf{Ö}_{\text{ð ãã.ì í}}$ **=** $\mathbf{Ç}_{\text{ð ãã}}$ **/ (**$\mathbf{W}_{\text{ñðàá}}$ **+** $\mathbf{W}_{\text{ì í.íàï .ãîä}}$**)** \$/m^3 **(2.2.4)**

Where: $\mathbf{W}_{\text{ì í.íàï .ãîä}}$ **–** reservoir storage for the entire year, million m^3

The cost of multi-year flow regulation, when annual $\mathbf{W}_{\text{ð ãã}}$ **< 0** and the previous multi-year water reserves of the reservoir are drawn down, should be determined through the analysis of flow regulation for a series of years.

3. Results of Calculation

Calculations are carried out for two scenarios of natural flow of the Naryn River **(**$\mathbf{W}_{\text{á}}$**):** inflows to the Toktogul Reservoir in a dry year (e.g., 1986) and a normal year (e.g., 1990).

3.1 Allocation of Costs Based on the Principle of Evaluating the Effects in Energy and Irrigated Agriculture Resulted from Flow Regulation

The results of calculations, which are carried out to determine volumes of the flow regulated by the Toktogul Reservoir (including storage and drawdown) for dry and normal years, are shown in Tables 3.1.2 and 3.1.3. These results are shown in Figures 3.1.1 and 3.1.2 as well. The demands of hydroenergy to the flow of the Naryn River are given in Table 3.1.1.

The results of calculations for power generation are shown in Table 3.1.4. The results of calculations for effects from regulation are shown in Table 3.1.5.

Table 3.1.1
Calculation of Energy Demands to the Naryn Cascade of HPPs

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
$N_{\text{êàñê}}$, ÌW	1567	1649	1380	1094	728	688	669	660	691	958	1156	1564
$Q_{\text{ýí}}$, m^3/second	553	582	487	386	257	243	236	233	244	338	408	552
$W_{\text{ýí}}$, million m^3	1483	1455	1305	1000	688	629	632	624	632	907	1057	1479

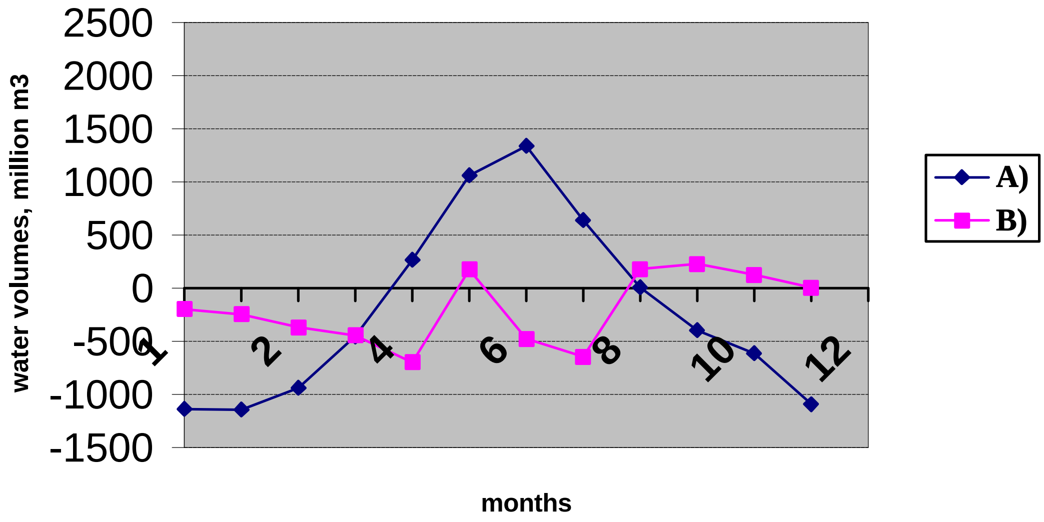
Table 3.1.2
Calculation of Volumes of the Flow Regulated by the Toktogul Reservoir to Satisfy the Demands of Energy ($W_{\text{ðãã.á.-ýí}}$) and Irrigation ($W_{\text{ðãã.á-èð}}$) in Dry and Normal Years, million m^3

Symbols	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Water demands													
$W_{\text{òð. ýí}}$	1483	1455	1305	1000	688	629	632	624	632	907	1057	1479	11891
DRY YEAR													
$W_{\text{á.ì .}}$	346	312	367	547	956	1690	1969	1264	640	511	446	388	9671
$W_{\text{òð.èð.ì .}}$	0	0	300	990	1650	1510	2450	1900	500	300	300	0	9900
$W_{\text{ðãã.á-ýí.ì}}$	-1137	-1143	-938	-453	268	1061	1337	640	8	-396	-611	-1091	-2455
$W_{\text{ðãã.á-èð.ì}}$	346	312	67	-443	-694	180	-481	-636	140	211	146	388	-464
Normal Year													
$W_{\text{á.ñð}}$	431	365	426	609	2137	3012	2068	1521	796	544	505	469	12883
$W_{\text{òð.èð.ñð.}}$	0	0	200	600	900	1300	1800	1500	450	200	200	0	7150
$W_{\text{ðãã.á-ýí.ì}}$	-1052	-1090	-879	-391	1449	2383	1436	897	164	-363	-552	-1010	992
$W_{\text{ðãã.á-èð.ñð}}$	431	365	226	9	1237	1712	268	21	346	344	305	469	5733

(-) means the required drawdown of the reservoir reserves

Fig 3.1.1

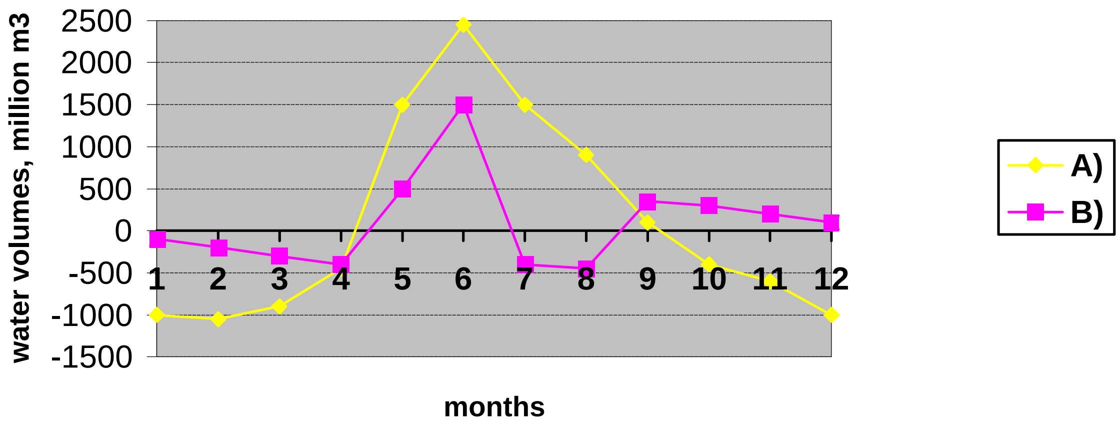
Flow Regulation to Satisfy Energy and Irrigation Demands in the Dry Year



A) Wðåã.á-ýí
B) Wðåã.á-èð. ì

Fig. 3.1.2

Flow Regulation to Satisfy Energy and Irrigation Demands in the Normal Year



A) $W_{\text{ðåã.á-ýí}}$
B) $W_{\text{ðåã.á-èð.ñð}}$

Table 3.1.3
Allocation of the Regulation ($W_{\text{ðåã.á-èð}}$, $W_{\text{ðåã.á-èð}}$) And Drawdown ($W_{\text{ñðàá.á-ýí}}$, $W_{\text{ñðàá.á-èð}}$) Volumes of the Toktogul Reservoir by Periods, million m^3

Symbols	Dry Year			Normal Year		
		Growing Season	Ungrowing Season		Growing Season	Ungrowing Season
$W_{\text{á}}$	9436	7066	2370	12883	10143	2740
$W_{\text{ýí.òð}}$	11891	4205	7686	11891	4205	7686
$W_{\text{èð.òð}}$	9900	9000	900	7150	6550	600
$W_{\text{ðåã.á-ýí}}$	-2455	2861	-5316	992	5938	-4946
$W_{\text{ðåã.á-èð}}$	-464	-1934	1470	5733	3593	2140
$W_{\text{ñðàá.ýí}}$	-5769	-453	-5316	-5337	-391	-4946
$W_{\text{ñðàá.èð}}$	-2254	-2254	0	0	0	0

Table 3.1.4
Power Generation of the Naryn Cascade to Satisfy Energy Demands (Å)
Based on the Reservoir Drawdowns in Dry (Eðåã. ì) and Normal Years (Eðåã.ñð),
Million kWh

Symbols	Jan	Feb	MAR	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Gr. Season	Ungr. Season
Å	1177	1141	1040	788	546	496	502	495	498	720	833	1174	9410	3325	6085
Eðåã. ì	894	901	737	356	0	0	0	0	0	311	481	857	4535	356	4181
Eðåã.ñð	827	859	691	308	0	0	0	0	0	285	435	794	4199	308	3891

Table 3.1.5
Calculation of the Effects in Energy and Irrigation Resulted from Regulation of the Naryn River Flow in Dry and Normal Years

Symbols	Jan	Feb	Mar	APR	May	Jun	Jul	Àug	Sep	Oct	Nov	Dec	Year
Dry year													
$E_{\text{ðãã}}$,	894	901	737	356	0	0	0	0	0	311	481	857	4535

Symbols	Jan	Feb	Mar	APR	May	Jun	Jul	Àug	Sep	Oct	Nov	Dec	Year
million. kWh													
Ñýí, cents/kWh	0,16	0.245	0.272	0.237	0.12	0.06	0.05	0.07	0.15	0.28	0.49	0.66	0.23
Öýí, cents/kWh	1.384	1.384	1.384	1.384	1.384	1.384	1.384	1.384	1.384	1.384	1.384	1.384	1.384
Ýýí.ì million $	10.94	10.26	8.20	4.08	0	0	0	0	0	3.43	4.30	6.20	**47.42**
Wñðàá.èð.ì million m^3	0	0	0	443	694	0	481	636	0	0	0	0	2254
Ýèð.ì , million $	0	0	0	5.76	9.02	0	6.25	8.27	0	0	0	0	**29.3**
Normal year													
Eð ãã, million kWh	827	859	691	308	0	0	0	0	0	285	435	794	4199
Ñýí, cents/kWh	0,16	0,245	0,272	0,237	0,12	0,06	0,05	0,07	0,15	0,28	0,49	0,66	0,23
Öýí, cents/kWh	1.384	1.384	1.384	1.384	1.384	1.384	1.384	1.384	1.384	1.384	1.384	1.384	1.384
Ýýí.ñð million $	10.12	9.78	7.68	3.53	0	0	0	0	0	3.15	3.89	5.75	**43.91**
Wñðàá.èð.ñð, million m^3	0	0	0	0	0	0	0	0	0	0	0	0	0
Ýèð.ñð, million.$	0	0	0	0	0	0	0	0	0	0	0	0	**0**

3.2 Allocation of Costs Based on the Principle of Evaluating Volumes and Cost of the Flow Regulated by the Toktogul Hydrosystem

Initial volumes of storage and drawdown of the reservoir for a year, which were used to calculate the cost of flow regulation, are shown in Table 3.2.1

Table 3.2.1
Calculation of the Toktogul Hydrosystem Flow Regulation Cost , million.m^3

Symbols	Dry Year		Normal Year	
	Energy Mode	**Irrigation Mode**	**Energy Mode**	**Irrigation Mode**
Wð ãã,	+992	+5733	-2455	-464
Including:				
W íàï	+6329	+5733	+3314	+1790
Wñðàá	-5337	0	-5769	-2254

For a normal year (the case, when **$W_{ðåã}$ > 0**), we determine the cost of regulation and allocation of costs between energy and irrigation, calculated through the cost and volume of regulation, as follows.

The cost of regulation:

$Ö_{ðåã.}$ = $Ç_{ðåã}$/($W_{ñðàá.}$+$W_{ì\ í.íàï\ .ãîä}$) = 37.8/(5337 + 5733 + 992) = 0.003134 [$/m3] …..(3.2.1)

For the first year of calculation, the cost of seasonal regulation and the cost of multi-year regulation coincide. The cost of multi-year regulation should be updated every year. For this purpose, it is necessary to carry out calculations for a series of years.

In the calculations of the cost of multi-year regulation, we adopted a series of actual operation modes of the Toktogul Reservoir from 1991 to 1996. The volumes of drawdown and storage of the reservoir are shown in Table 3.2.2.

Table 3.2.2

Designation	**1991-1992**			**1992-1993**			**1993-1994**			**1994-1995**			**1995-1996**		
	Drawdown	Storage	Annual Regulation	Drawdown	Storage	Annual Regulation	Drawdown	Storage	Annual Regulation	Drawdown	Storage	Annual Regulation	Drawdown	Storage	Annual Regulation
Drawdown (-), Storage (+) billion m^3	-2.25	+2.55	+0.3	-3.06	+6.06	+3.0	-4.7	+5.3	+0.6	-5.2	+1.5	-3.7	-5.3	+4.7	-0.6

Table 3.2.3

Designation	**1991-1992**	**1992-1993**	**1993-1994**	**1994-1995**	**1995-1996**
Cost of Multi-year Regulation, $/$m^3$	(37.8 + **21.1**)/(2250 + 300 + **5733**) = 0.0071	(37.8 + **0.0071*300**)/(3060 + 3000 + **300**) = 0.0063	(37.8 + **0.0063*3000**)/(4700 + 600 + **3000**) = 0.0068	(37.8 + **0.0068*600**)/(5200 + **600**) = 0.0072	**-**

The costs of seasonal regulation:

$Ç_{ðåã.ñåç.}$ = $Ö_{ðåã}$ * $W_{ñðàá}$ = 0.003134*5337 = 16.7 [million $] ……………………(3.2.2)

Including:
Ç$_{\text{ðãã.ñåç.èð}}$ = Ö$_{\text{ðãã}}$ * W$_{\text{ñðàá}}$ = 0.003134*0 = 0 [million $] …………………………(3.2.3)
Ç$_{\text{ðãã.ñåç.ýí}}$ = Ö$_{\text{ðãã}}$ * W$_{\text{ñðàá}}$ = 0.003134*5337 = 16.7 [million $] ……………………(3.2.4)
The costs of multi-year regulation for 1990-1991
Ç$_{\text{ðãã. ì ííã.}}$ = Ö$_{\text{ðãã}}$ * W$_{\text{ì í.íàï .ãîä}}$ = 0.003134*(5337 + 992) = 21.1 [million $]
…………(3.2.5)

Calculation results are shown in Table 3.2.4.

<u>ALLOCATION OF COSTS FOR A NORMAL YEAR, MILLION $</u>

Designation	**Seasonal**
Costs of Regulation	16.7
For Irrigation	0
For Energy	16.7

For a dry year, when annual value **W$_{\text{ðãã}}$ < 0** and the prior multi-year reserves of the reservoir are drawn down, the cost of seasonal regulation is determined as follows.

Ö$_{\text{ðãã.ñåç}}$ = Ç$_{\text{ðãã}}$/W$_{\text{ñðàá.ñåç}}$ = 37.8/5104 = 0.0074 [$/m^3]…………………(3.2.6)
Where,
W$_{\text{cðàá.ñåç}}$ = W$_{\text{ñðàá}}$ – W$_{\text{ðãã}}$ = (5769 + 2254) – (2455 + 464) = 5104 million m^3………….(3.2.7)

The costs of seasonal regulation:

Ç$_{\text{ðãã.ñåç.èð}}$ = Ö$_{\text{ðãã.ñåç}}$*W$_{\text{ñðàá.èð}}$ = 0.0074*1790 = 13.3 [million $] ……………….(3.2.9)
Ç$_{\text{ðãã.ñåç.ýí}}$ = Ö$_{\text{ðãã}}$*W$_{\text{ñðàá.ýí}}$ = 0.0074*3314 = 24.5 [million $] ……………….(3.2.10)

The results of calculation are shown in Table 3.2.5.

<u>ALLOCATION OF COSTS FOR A DRY YEAR, MILLION $</u>

Designation	**Seasonal**
Costs of Regulation	37.8
<u>FOR IRRIGATION</u>	13.3
For Energy	24.5

4. Conclusions

In the materials prepared for the Central Asian Mission of the US Agency for International Development, (Report No. 7 “Analysis of Variants of Operation of the Toktogul Reservoir,” J. Keith, D. McKinney), it is recommended to adopt usable storage of reservoir as a basis of calculation for prorated cost allocation.

In our opinion, this is not quite correct, because in this case natural flow, which is partially used for power generation and irrigation, is not taken into account. We think that the approach based on equal cost allocation between all users is not acceptable due to absence of an allocation criterion. The approach based on the cost allocation on demand (at a request for irrigation releases) is not practicable, since the share of O&M costs of Kazakhstan and Uzbekistan may not cover possible losses of the Kyrgyz Republic, if the Toktogul Hydrosystem is operated under the irrigation mode only. We believe, that the most acceptable approach of the recommended in Report #7 is the approach based on the complete recovery of O&M costs by the Kyrgyz Republic with obligatory compensation of losses by other republics. Moreover, this approach reflects the current procedure of making mutual payments.

Calculations in the approach, which we propose, are based on the value of volume of the flow regulated by the Toktogul Hydrosystem. However, this approach has one drawback: only operation of the Toktogul Reservoir is taken into consideration in the basin. The Charvak, Andijan, Kairakkum and Chardara Reservoirs are not taken into account. Whereas, only the joint operation schedule of all reservoirs determines the cost of flow regulation in the basin. This cost will have different values depending on operation modes and a type of regulation.

Therefore, it is essential to refine the cost of regulation for each reservoir of the basin in further elaboration. This cost should be divided into two components, the seasonal cost and the multi-year cost. The cost should be evaluated depending on the operation modes of reservoirs.

3. System of Technical and Economic Indicators to Determine, Calculate and Allocate Costs Associated with the Joint Use of Facilities the Naryn-Syr Darya Water Management System (WMS)

To determine, calculate and allocate costs and benefits associated with the operation of the complex of WMS facilities as a whole and the component thereof, to determine shares of sectors and republics, which jointly use objects of the complex, in total costs and benefits, the system of technical and economic indicators is developed. It is provided with the methods to calculate these indicators.

3.1 Major adopted parameters used to determine cost indicators:

K – book (replacement) value of fixed assets of the water complex facilities;

È – annual costs of operation, routine and capital repair, depreciation to renovate fixed assets of the water complex facilities.

$Ï_{\text{ð}}$ – discounted costs associated with the operation of WMS facilities.

3.1.1 Cost of total and sectoral fixed assets of the WMS facilities is determined through the following equations:

1. $\sum \hat{E}_{\text{ÂÕÊ}} = \hat{E}_{\text{êîì ïë.ã/óç}} + \hat{E}_{\text{ÃÝÑ}} + \hat{E}_{\text{ÁÂÎ}} + \hat{E}_{\text{ð.Ì ÑÂÕ}}$

2. $\sum \hat{E}_{\text{ÂÕÊ}} = \hat{E}_{\text{ÂÕÊ.è.}} + \hat{E}_{\text{ÂÕÊ.ýí.}}$

3. where $\sum \hat{E}_{\text{êîì ï.ã/óç.}} = \hat{E}_{\text{êîì ïë.ã/óç.èð.}} + \hat{E}_{\text{êîì ïë.ã/óç.ýí.}}$

Thus,

4. $\sum \hat{E}_{\text{ÂÕÊ}} = \left(\hat{E}_{\text{êîì ïë.ã/óç.èð.}} + \hat{E}_{\text{êîì ïë.ã/óç.ýí.}}\right) + \hat{E}_{\text{ÃÝÑ}} + \hat{E}_{\text{ÁÂÎ}} + \hat{E}_{\text{ð.Ì ÑÂÕ}}$

Where:

$\hat{E}_{\text{ÂÕÊ}}$ **– fixed assets of the entire WMS, million $;**

$\hat{E}_{\text{ÂÕÊ.èð.}}$ fixed assets of the WMS related to irrigation, million $;

$\hat{E}_{\text{ÂÕÊ.ýí.}}$ – fixed assets of the entire WMS related to energy, million $;

$\hat{E}_{\text{êîì ï.ã/óç.}}$ – fixed assets of the regulating complex hydrosystems (reservoirs) serving irrigation and energy, million $;

$\hat{E}_{\text{êîì ïë.ã/óç.èð.}}$ - fixed assets of the complex hydrosystems in part related to irrigation, million $;

Ê$_{\text{êîìïë.ã/óç.ýí.}}$ – fixed assets of the complex hydrosystems in part related to hydroenergy, million $;

Ê$_{\text{ÃÝÑ}}$ – fixed assets of the hydropower plant cascade of WMS, million $;

Ê$_{\text{ÁÂÎ}}$ – fixed assets of BVO Syr Darya, million $;

Ê$_{\text{ð. ÌÑÂÕ}}$ – fixed water management assets of the republics' Ministries of Agriculture and Water Management, million $.

3.1.2 Total and sectoral annual costs associated with operation, repairs and depreciation to renovate fixed assets of the WMS facilities are determined through the following equations:

5. $\sum \text{È}_{\text{ÂÕÊ}} = \text{È}_{\text{êîìïë.ã/óç.}} + \text{È}_{\text{ÃÝÑ}} + \text{È}_{\text{ÁÂÎ}} + \text{È}_{\text{ð.Ì ÑÂÕ}}$

6. $\sum \text{È}_{\text{ÂÕÊ}} = \text{È}_{\text{ÂÕÊ.èð.}} + \text{È}_{\text{ÂÕÊ.ýí.}}$

7. where $\sum \text{ÈÊ}_{\text{êîìï.ã/óç.}} = \text{È}_{\text{êîìïë.ã/óç.èð.}} + \text{È}_{\text{êîìïë.ã/óç.ýí.}}$

Thus,

8. $\sum \text{È}_{\text{ÂÕÊ}} = \left(\text{È}_{\text{êîìïë.ã/óç.èð.}} + \text{È}_{\text{êîìïë.ã/óç.ýí.}}\right) + \text{È}_{\text{ÃÝÑ}} + \text{È}_{\text{ÁÂÎ}} + \text{È}_{\text{ð.Ì ÑÂÕ}}$

Where,

È$_{\text{ÂÕÊ}}$ – total annual costs of operation, repairs and depreciation of fixed assets of the entire WMS, million $;

È$_{\text{ÂÕÊ.èð.}}$ – total costs of WMS related to irrigation, million $;

È$_{\text{ÂÕÊ.ýí.}}$ – total costs of WMS related to energy, million $;

È$_{\text{êîìï.ã/óç.}}$ – annual costs of operation, repair and depreciation to renovate fixed assets of the complex hydrosystems (reservoirs), million $;

È$_{\text{êîìïë.ã/óç.èð.}}$ – annual costs of the complex hydrosystems related to irrigation, million $;

È$_{\text{êîìïë.ã/óç.ýí.}}$ – annual costs of the complex hydrosystems related to hydroenergy, million $;

È$_{\text{ÃÝÑ}}$ - annual costs of operation, repair and depreciation of fixed assets concerning the hydropower plant cascade of WMS, million $;

ÈÁÂÎ – annual costs of operation, repair and depreciation to renovate fixed assets of BVO Syr Darya, million $;

Èð. ÌÑÂÕ – annual costs of operation, repair and depreciation regarding fixed assets of the republics' Ministries of Agriculture and Water Management (ÌÑÂÕ), million $.

3.1.3 Total and sectoral discounted costs of the WMS facilities are determined through the following equations:

9. $\sum \text{Ï ð}_{\text{ÂÕÊ}} = \text{Ï ð}_{\text{êîì ïë.ã/óç.}} + \text{Ï ð}_{\text{ÃÝÑ}} + \text{Ï ð}_{\text{ÁÂÎ}} + \text{Ï}\ _{\text{ð.Ì ÑÂÕ}}$

10. $\sum \text{Ï ð}_{\text{ÂÕÊ}} = \text{Ï ð}_{\text{ÂÕÊ.èð.}} + \text{Ï ð}_{\text{ÂÕÊ.ýí}}.$

11. where $\sum \text{Ï ð}_{\text{êîì ï .ã/óç.}} = \text{Ï ð}_{\text{êîì ïë.ã/óç.èð.}} + \text{Ï ð}_{\text{êîì ïë.ã/óç.ýí}}.$

Thus,

12. $\sum \text{Ï ð}_{\text{ÂÕÊ}} = \left(\text{Ï ð}_{\text{êîì ïë.ã/óç.èð.}} + \text{Ï ð}_{\text{êîì ïë.ã/óç.ýí}}.\right) + \text{Ï ð}_{\text{ÃÝÑ}} + \text{Ï ð}_{\text{ÁÂÎ}} + \text{Ï ð}_{\text{ð.Ì ÑÂÕ}}$

Where,

<u>Ï ðÂÕÊ **– total discounted costs of the entire WMS, million $;**</u>

Ï ð ÂÕÊ.èð. – total discounted costs of WMS related to irrigation, million $;

Ï ð ÂÕÊ.ýí. - total discounted costs of WMS related to energy, million $;

Ï ð êîìï.ã/óç. – discounted costs of the complex hydrosystems of WMS, million $;

Ï ð êîìïë.ã/óç.èð. – discounted costs of the complex hydrosystems related to irrigation, million $;

Ï ð êîìïë.ã/óç.ýí. – discounted costs of the complex hydrosystems related to energy, million $;

Ï ð ÃÝÑ – discounted costs of the hydropower plants of WMS, million $;

Ï ð ÁÂÎ – discounted costs of BVO Syr Darya, million $;

Ï ð ð. ÌÑÂÕ – discounted costs of the republics' Ministries of Agriculture and Water Management, million $.

3.2 Determination, calculation and allocation of benefits (effects) from the use of the WMS facilities is carried out using the following indicators:

3.2.1 Effect in the energy sector is determined based on the electric power generated by the hydropower plant cascade of WMS (of a complex hydrosystem). The effect is expressed by the indicator of net income from the sale of electric power:

13. $\times\text{Ä}_{\text{ýí.}} = \text{Âï}_{\text{ýí.}} - \text{Ñ}_{\text{ýí.}}$

14. or $\times\text{Ä}_{\text{ýí.}} = \text{ÏÐ}_{\text{ýí.}} + \text{Ç}_{\text{òð.ýí.}}$

Where:
×Ä$_{\text{ýí.}}$ – net income of the electric power generation, million $;

Âï$_{\text{ýí.}}$ – cost of gross output of the electric power generation, million $;

Ñ$_{\text{ýí.}}$ – cost (costs) of the electric power generation, million $;

ÏÐ$_{\text{ýí.}}$ – benefit resulted from the sale of electric power, million $;

Ç$_{\text{òð.ýí.}}$ – labor costs (wages) of the electric power generation, million $;

3.2.2 Total effect of irrigation is determined based on the output of irrigated agriculture. The total effect is expressed by the indicator of net income:

15. $\times\text{Ä}_{\text{îáù.îð.}} = \text{ÂÏ}_{\text{îáù.îð.}} - \text{È}_{\text{îáù.îð.}}$

16. or $\times\text{Ä}_{\text{îáù.îð.}} = \text{ÏÐ}_{\text{îáù.îð}} - \text{Ç}_{\text{îáù.îð.}}$

Where:
×Ä$_{\text{îáù.îð.}}$ – total net income of irrigated agriculture, million $;

×Ä$_{\text{îáù.îð.}}$ – total cost of gross output of irrigated agriculture, million $;

È$_{\text{îáù.îð.}}$ – total costs (cost) of agricultural production, million $;

ÏÐ$_{\text{îáù.îð.}}$ – total benefit from the sale of agricultural output, million $;

Ç$_{\text{îáù.îð.}}$ – total labor costs of agricultural production, million $.

Given the share of water factor in the receiving of net income and effect from the adjoint sectors, the equation of net income gains the following shape:

17. $\times\text{Ä}_{\text{îð}} = \left(\text{Âï}_{\text{îð}} - \text{È}_{\text{îð}}\right)\times\left(0.3\times1.5\right)$

Coefficient 0.3 – the share of water factor in the formation of total agricultural productivity on irrigated lands;

Coefficient 1.5 – the share of total effect of irrigated agriculture received in the adjoint sectors.

3.3 To carry out necessary calculations, it is recommended to use a series of volumetric indicators characterizing availability and utilization of water resources of WMS.

$W_{\text{ãîä}}$ **– annual allowed water diversion from the rivers of WMS, million m^3.**

$W_{\text{âåã}}$ – allowed water diversion from the rivers of WMS during the growing season, million m^3.
$W_{\text{ðåã.âåã.}}$ – part of water diversion during the growing season provided by the use of all WMS facilities, million m^3.
$W_{\text{á.ñò.}}$ – natural flow of the WMS rivers, million m^3.
$W_{\text{ðåã.ýí.}}$ – amount of flow regulated to meet energy demands, million m^3.
$W_{\text{ðåã.èð.}}$ – amount of flow regulated to meet irrigation demands, million m^3.
$M_{\text{îð.îáù.}}$ – total area of irrigated lands in the WMS basin, thousand ha.
$M_{\text{îð.ðåã.}}$ – area of irrigated lands in the influence zone of the WMS flow regulation, thousand ha.

(Below, Table O shows volumetric indicators for the Naryn-Syr Darya Water Management System).

The recommended system of indicators is designed to calculate and allocate costs and benefits both for the entire WMS and individual complex and other facilities jointly used by countries and sectors of economy.